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THE EFFECTS OF INTERRUPTION OF DARK ADAPTATION ON PERFORMANCE OF TWO MILITARY TASKS AT NIGHT

David L. Easley, et al

Human Resources Research Organization
Alexandria, Virginia

December 1969

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David L. Easley, Donald L. Wright,
William N. Warnick, and William N. Gipe

HumRRO Division No. 2

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Contract DAHC 19-70-C-0012

HumRRO

HUMAN RESOURCES RESEARCH ORGANIZATION

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HumRRO Division No. 2
Fort Knox, Kentucky
HUMAN RESOURCES RESEARCH ORGANIZATION

Technical Report 69-20
Work Unit NIGHTSIGHTS
Sub-Unit I

The Human Resources Research Organization (HumRRO) is a nonprofit corporation established in 1969 to conduct research in the field of training and education. It is a continuation of The George Washington University, Human Resources Research Office. HumRRO's general purpose is to improve human performance, particularly in organizational settings, through behavioral and social science research, development, and consultation. HumRRO's mission in work performed under contract with the Department of the Army is to conduct research in the fields of training, motivation, and leadership.

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FOREWORD

The over-all objectives of Work Unit NIGHTSIGHTS are to identify critical human factors problems in the use of new passive night vision devices, and to develop effective techniques of training in the use of the devices. The Work Unit is an outgrowth of an Exploratory Study (ES-19), Night Devices Training, begun in FY 1964 to develop a technique for scaling the visual requirements of various Army tasks and relating the requirements to military performance. At the request of the U.S. Army Combat Developments Command Armor Agency, ES-19 was redirected in FY 1965 to determine the impact of new night vision equipment on training and performance.

This report describes the studies conducted under NIGHTSIGHTS Work Sub-Unit I, Effects of Loss of Dark Adaptation on Performance in Representative Field Situations.

The NIGHTSIGHTS research is being conducted by HumRRO Division No. 2 at Fort Knox, Kentucky. Dr. Norman Willard, Jr. was Director of Research during the data collection phase of this research. Dr. Donald Haggard is the present Director. Dr. David Easley was the Work Unit Leader under whom this research was conducted.

Military support for the NIGHTSIGHTS I research was provided by the U.S. Army Armor Human Research Unit, Fort Knox. During data collection, COL Charles H. Brown was Chief of the Unit. LTC John A. Hutchins, Jr. is the present Chief.

HumRRO research for the Department of Army is conducted under Army Contract DAHC 19-70-C-0012 and Army Project 2Q062107A712, Training, Motivation, Leadership Research.

Meredith P. Crawford
President
Human Resources Research Organization

SUMMARY AND CONCLUSIONS

Military Problem

Image intensifiers are a new family of night vision devices which expose the user to a green-hued image whose brightness is above the normal photopic threshold. For this reason employment of these devices interrupts dark adaptation—a consequence of no small concern to the soldier who must perform various tasks at night after laying the instrument aside. Before the introduction of intensifiers, military effort was devoted to the development and implementation of procedures which prevent or curtail the loss of dark adaptation, not to a practical assessment of the disruption of performance which attends the loss. The wide acceptance of intensifiers means that such an assessment is now mandatory.

Research Approach

The experiments reported here were an investigation of the negative impact of the interruption of dark adaptation by a simulated intensifier on the performance of two military tasks with unaided vision at night: (a) walking parallel to a ground-mounted guideline, keeping as far to the right of it as possible (such guidelines being used by the Army to alert and guide soldiers who are moving cross-country at night through or near hazardous areas), and (b) firing the M14 rifle at stationary silhouette targets.

Method

The four studies in Experiment I (70 subjects) considered the effects of (a) different conditions of interruption of dark adaptation by intensifier employment, and (b) readaptation intervals, on the distance that the subject could maintain from the guideline as he followed it.

Study 1 was a comparison of no dark adaptation interruption in either eye with interruption in one eye for five minutes and interruption alternately in both eyes for 10 minutes.

Study 2 was a comparison of six minutes of readaptation to the dark with three minutes and 0 minutes of readaptation, after five minutes of interruption simultaneously in both eyes.

Study 3 was a comparison of two minutes of readaptation to the dark with one minute and 0 minutes of readaptation, after five minutes of interruption simultaneously in both eyes.

Study 4 was a comparison of two minutes of readaptation to the dark with one minute and 0 minutes of readaptation, after five minutes of interruption in one eye.

The three studies in Experiment II (54 subjects) explored time to first round, duration of fire, and target hits in firing the M14 rifle, as a function of (a) no dark adaptation interruption, (b) interruption in the shooting eye for five minutes, and (c) interruption alternately in both eyes for 10 minutes. Time to first round includes the time consumed in acquiring the target and delivering the first round. Duration of fire refers to the time between the delivery of the first and final rounds in response to a "fire when ready" firing order.

The design of Studies 2 and 3 in Experiment I reflects the use of simulated binocular intensifiers. The design of the other studies in both experiments reflects the use of simulated monocular intensifiers. In both Study 1 of Experiment I and the three studies of Experiment II (Studies 5-7), exposure to the task situation immediately followed dark adaptation interruption by an intensifier. In Studies 2, 3, and 4 of Experiment I, a readaptation interval followed interruption of dark adaptation and thus preceded task performance.

Results

(1) With no interruption of dark adaptation, the guideline could be seen and followed at a 20% greater distance than with dark adaptation interrupted alternately in both eyes, and at a 10% greater distance than with interruption in one eye.

(2) After simultaneous interruption of dark adaptation in both eyes, between two and three minutes of readaptation to the dark were required to restore guideline performance to the level achieved with dark-adapted vision.

(3) Readaptation to the dark after interruption of dark adaptation in one eye did not affect guideline performance.

(4) Compared with performance under dark-adapted vision, interruption of dark adaptation both in one eye and alternately in both eyes increased time to first round by two to three minutes, and duration of fire by more than half a minute. But such interruptions of dark adaptation did not affect target hits.

Conclusions

(1) Interruption of dark adaptation by employment of monocular intensifiers in either one or both eyes lessens the distance at which a guideline can be seen and followed at night with unaided eyes. The man walks nearest to the guideline after both eyes have been exposed to the instrument. Consequently, unless time is allowed for readaptation to the dark, men will walk closer to perilous areas after dark adaptation is interrupted with a monocular intensifier.

(2) Operators of binocular intensifiers who may encounter guidelines while moving cross-country with unaided vision at night should be permitted three minutes of readaptation to the dark after laying the instrument aside.

(3) Further study is needed to determine the readaptation interval required, after the use of monocular intensifiers, to restore performance to what was achieved with dark-adapted vision.

(4) Interruption of dark adaptation by employment of monocular intensifiers, in either one or both eyes, decreases the speed with which a rifleman can engage and fire at a target in the dark with unaided vision. Thus, unless the effects of dark adaptation interruption have been dissipated by readaptation, men who have just employed monocular intensifiers will begin and continue to fire their rifles more slowly.

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The Effects of Interruption of Dark Adaptation on Performance of Two Military Tasks at Night

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INTRODUCTION

MILITARY PROBLEM

When military operations have been conducted at night in the past, every effort has been made to maintain the dark-adapted state of the soldier's eyes. Use of artificial illumination is curtailed; if such illumination is essential to accomplishing an assignment, red filters are employed.

This blackout procedure has become standard in conducting night actions because the dark-adapted eye is much more sensitive than the eye stimulated by light. In laboratory tests, light that is slightly above threshold in intensity and shown for less than one minute has caused a loss in sensitivity amounting to two or more log units of illuminance (1, 2). In the field at night, this means that if a soldier who is operating proficiently under heavy clouds and no moon suffers a two-log loss of visual sensitivity, he will need a cloudless sky and a quarter moon to regain his proficiency immediately.[1] The environment is seldom so accommodating. If the occasional interruption of dark adaptation is a predictable consequence of night operations, the decrement in field performance that would be associated with this visual loss should be quantified.

These interruptions of dark adaptation may occur, for example, during the employment of image intensifiers, a new family of passive night vision devices. These monocular instruments present the user with a green-hued image of considerable brightness, and are widely used by enlisted men in Vietnam for night surveillance. A soldier employs the sights intermittently on a watch lasting as long as 30 minutes. During the watch he makes several uninterrupted and methodical scans of a potentially contestable area. Under these conditions, dark adaptation cannot be maintained.

A situation exists, then, in which some soldiers may experience a loss of dark adaptation and a decrease in ability to perform nonscanning tasks during the normal course of night operations. It is difficult, however, to estimate the magnitude and duration of this decrement in the field on the basis of laboratory activity which entails a minimum of overt, sustained responses.[2] Furthermore, in recognizing the problem of visual degradation, the military has been concerned with developing procedures to preserve dark adaptation rather than assessing the impairment of performance which accompanies its loss (3).

GENERAL APPROACH

The research reported here was an effort to assess the effects of interruption of dark adaptation by intensifier employment on the subsequent performance of two representative military tasks with unaided vision at night. For the first task, Experiment I, soldiers walked parallel with a continuous white guideline, always keeping as far to the right of the line as possible. The line, taking different directions as it progressed, lay along the left side of a field whose dimensions were 70x100 feet. The other task, Experiment II, involved the delivery of aimed rifle fire on silhouette targets.

[1] The rationale for this statement is contained in a consulting report on the use of image intensifiers, prepared by D.L. Wright of HumRRO Division No. 2 in March 1968.

[2] Most of the laboratory work on dark adaptation is summarized in References 1 and 2.

EFFECTS OF INTERRUPTION OF DARK ADAPTATION, BY INTENSIFIER USE, ON FOLLOWING A GUIDELINE (EXPERIMENT I)

PROBLEM AND APPROACH

Image intensifiers are employed by ground troops in Vietnam as surveillance instruments on defensive perimeters, at patrol ambush sites, and at listening posts (4, 5). Even though the Starlight Scope, the most common intensifier in use in Vietnam, may be rifle-mounted, it is usually hand-held and employed mainly for target detection. In accord with a frequently used operating procedure, either tentative or definite detection of enemy troops leads immediately to saturation of the target area with fire, a practice which minimizes the additional applications of the Scope as a sight for direct firing and as an aid to target recognition/identification.[3]

In Vietnam and in future conflicts, a foot soldier may be required to perform many nonscanning tasks at night after laying aside a hand-held intensifier. For example, he may have to assign others to battle position, fire his weapon into a preselected sector, carry out maintenance on various items of equipment, use a radio, or drive a vehicle. He may also be required to move on foot from one general location to another, and during this movement he may encounter dangerous situations or impassable obstacles, such as swamps, minefields, a precipice, or areas of radiation.

Engineer's tape, anchored to the ground, is often used by the Army under darkness to mark perilous areas and identify circumventing routes of safe passage. The ability of a soldier who is walking cross-country to sense and follow these tape guidelines is almost sure to be affected by the previous employment of intensifiers which interrupt dark adaptation with an image of considerable brightness.

The four studies of Experiment I were designed to estimate the maximum lateral distance at which a guideline could be seen and followed with both unaided eyes at night after exposure to a simulated image intensifier. Positioning themselves so that the guideline was barely visible, subjects walked parallel to it after dark adaptation was interrupted by stimulation of one or both eyes. The latter condition was used because of the suggestion that fatigue effects (not specified) are lessened by alternating an intensifier from eye to eye (6). Within the four studies, interruption of dark adaptation by employment of a simulated intensifier was followed by walking beside the guideline, immediately or after one of several different readaptation intervals. Varying readaptation time had reference to the fact that visual sensitivity improves with time in the dark after light stimulation.

In essence, then, Experiment I—use of deviation from a guideline as an index of task ability—was designed to measure both the magnitude and the duration of task disruption as a function of monocular and binocular interruption of dark adaptation by a simulated intensifier. In all four studies, dark adaptation without interruption was used as a control condition.

RESEARCH METHOD

Apparatus

In an open field, three guideline patterns were constructed for Studies 1 through 4. A practice guideline was constructed from engineer's tape (Figure 1). The guideline pattern

[3] This information was obtained from interviews with Vietnam returnees.

shown in Figure 2 was used in Study 1; the pattern shown in Figure 3 was used in Studies 2, 3, and 4. The guidelines shown in Figures 2 and 3 were constructed of flat white molding one inch wide. Adjacent to these guidelines, a grid (70x100 ft.) was built by laying twine on the ground in a series of squares, five feet per side, as depicted in Figures 2 and 3.

As noted, the image intensifiers for the interruption of dark adptation were simulated. Infrared binoculars were mounted in one end of a shadow box. At the other end, a 12-inch spotlight bulb was centered and connected to a rheostat and a 12-volt battery. Milky white diffusing plastic was placed between the bulb and the binoculars, to provide uniform illumination at the objectives of the binoculars. A movable shutter which blocked out one objective of the binocular was placed in the box in such a way that the subject could move the shutter in front of either objective. Accordingly, the visual apparatus presented the viewer with a green-hued monocular field of view.

A Gamma Scientific Photometer,[4] Model Number 700, fitted with a Model 700-4 Cosine Receptor head that allowed direct foot-candle measurements, was used to maintain the level of eyepiece illumination at 4 foot-candles.[5] The same instrument was used to measure levels of ambient illumination during the course of the experiment. Each night the absolute calibration of the instrument was checked before its use with a Model 200-1 Luminance Standard from Gamma Scientific.

Subjects

A total of 71 enlisted men were used as subjects. Thirty subjects participated in Study 1, 10 in Study 2, 20 in Study 3, and 10 in Study 4. The subjects were trainees at the U.S. Army Training Center, Armor. Throughout the experiment, the subjects showed a high level of interest and enthusiasm that appeared to be sustained by the novelty of the experimental situation.

Descriptive data for all subjects, summarized in Appendix A, include age, rank, months in the Army, acuity scores on the Armed Forces Vision Tester, and scores on the Navy Night Vision Test.

Design

Study 1 was a comparison of the distances that could be maintained from a guideline as a function of (a) no interruption of dark adaptation, (b) a continuous 5-minute interruption of dark adaptation in the shooting eye with a

Practice Guideline for Experiment I

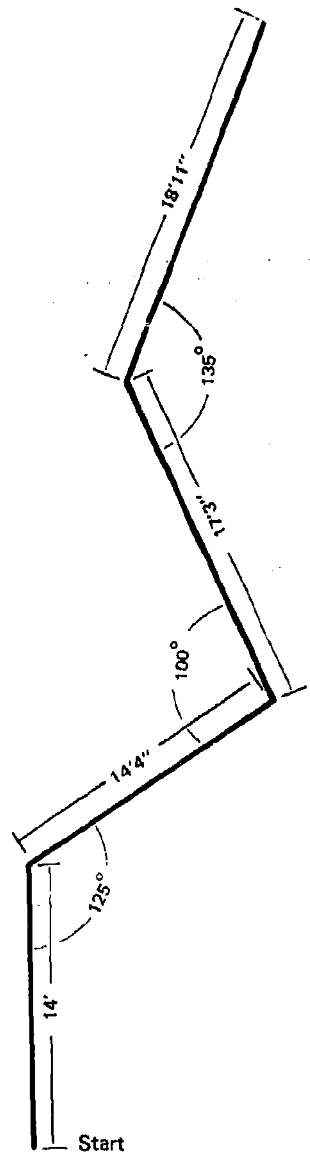

Figure 1

[4] Identification of the instruments described is for research documentation purposes only; their listing does not constitute an official endorsement by either HumRRO or the Department of the Army.

[5] This value was estimated as the average illumination of the Starlight Scope image during a 1965 visit to Warfare Vision Branch, Engineer Research and Development Laboratory.

Guideline Pattern and Grid for Study 1

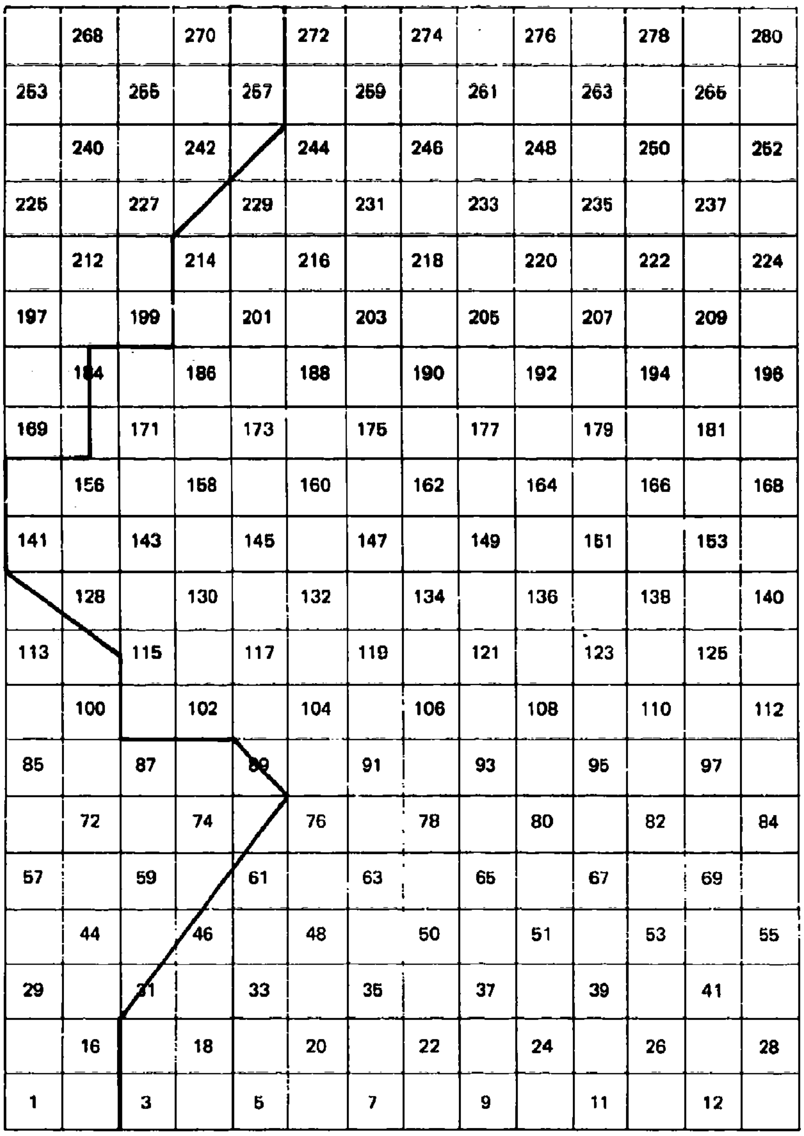

Figure 2

simulated intensifier, and (c) a 10-minute interruption of dark adaptation alternately in both eyes. For the second condition, the shooting eye was determined by asking the subject which eye he sighted with in firing a rifle. Under the third condition, the shutter in the shadow box was moved, exposing each eye alternately to light for a 60-second interval—a total of five nonsuccessive minutes of dark adaptation per eye.

Study 1 was conducted on three successive nights, with 10 subjects used each night. Each subject was administered all three experimental conditions in a random order. One

Guideline Pattern and Grid for Studies 2-4

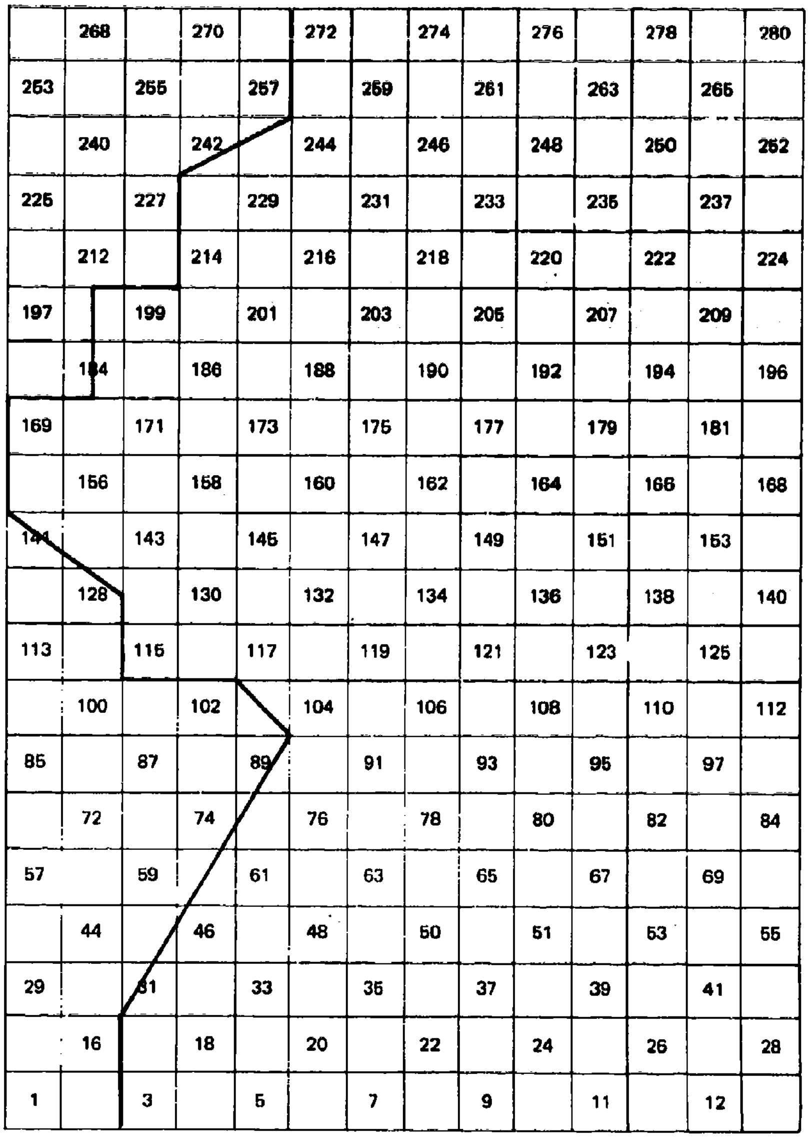

Figure 3

group of five subjects completed three experimental runs during the first half of a nightly session, the other group during the last half.

In Study 1, performance was assessed immediately after dark adaptation was interrupted; in Studies 2, 3, and 4, three different intervals of dark readaptation time elapsed between termination of the subject's exposure to the intensifier and his walk parallel to the guideline. The three experimental conditions of Study 2 were 0-, 3-, and 6-minute readaptation intervals. The three experimental conditions of Studies 3 and 4 involved 0-, 1-, and 2-minute readaptation intervals.

In Studies 2 and 3, the shutter was removed from the shadow box of the apparatus and both eyes were simultaneously stimulated for five successive minutes. In Study 4, the shutter was replaced and the shooting eye was stimulated for five successive minutes. Studies 1 and 4 were designed to reflect the use of monocular intensifiers, the only type currently available. Studies 2 and 3 were designed to reflect the use of future intensifiers which may be binocular.

All four studies of Experiment I were conducted under moonless skies. Data collection for Study 2 took one night; for Study 3, two consecutive nights; and for Study 4, one night. Each night the subjects were divided into two groups of five subjects each before being randomly run under all experimental conditions of the current study.

The conditions for the four studies of Experiment I are summarized in Table 1.

Table 1

Summary of the Conditions for the Four Studies of Experiment I

Study	*N* (Dark-Adapted)	Interruption of Dark Adaptation	Readaptation Interval	Comparison of Results
1	30	None; in One Eye for 5 Consecutive Min.; in Both Eyes, 1 Min. Alternately for 5 Min. Each.	None	Dark-Adapted Vision vs Interruption in One Eye vs Interruption Alternately in Both Eyes.
2	10	In Both Eyes Simultaneously for 5 Consecutive Min.	None; 3 Min.; 6 Min.	No Readaptation Interval vs 3 Min. of Readaptation vs 6 Min. of Readaptation.
3	20	In Both Eyes Simultaneously for 5 Consecutive Min.	None; 1 Min.; 2 Min.	No Readaptation Interval vs 1 Min. of Readaptation vs 2 Min. of Readaptation.
4	10	In the Shooting Eye for 5 Consecutive Min.	None; 1 Min.; 2 Min.	No Readaptation Interval vs 1 Min. of Readaptation vs 2 Min. of Readaptation.

Procedure

The subjects reported on the afternoon of the day they were to be tested. They were assembled as a group and were instructed about the task to be performed (see Appendix B). The general nature—but not the specific pattern—of the guideline was described. The subjects were directed to walk as far to the right of the guideline as possible and to mark their path by dropping a white poker chip each time their right foot hit the ground.

The formal instructional session was followed by trials on the practice guideline (Figure 1) during daylight hours. Each subject had one practice trial and wore 4.5 neutral density goggles, which impaired the subject's vision enough to suggest what the nighttime situation would be for him. Processing of subjects included administration of a personnel information questionnaire (Appendix C) and testing on the Armed Forces Vision Tester and the Navy Night Vision Test. (For data, see Appendix A.)

After the subjects in the first group had been run in the field at night, they were returned to the post area for release; the second group of subjects was then transported to the field area and run. It was necessary to divide the subjects into these small groups to maintain control in the field.

For ease of operation, the field situation was divided into three separate areas. Area 1 was a waiting area located about 200 feet from Area 2, the interruption of dark adaptation area, which was supplied with several chairs and two simulated image intensifiers on field tables. Directly adjacent was Area 3, containing the guideline and grid.

In Area 1, subjects were allowed to smoke but not to use any other illuminants. An experimenter was stationed there to maintain the area. At least 15 minutes (usually 20 minutes) before a subject was to walk the course, he was escorted from the waiting area to Area 2 by another experimenter. There he was given poker chips and was either dark adapted, exposed to light in one eye, or exposed to light in both eyes, depending on his assignment. All lights in Area 2 except the simulated intensifiers were covered with red filters. For dark adaptation, the subject simply sat with his back to Areas 1 and 3 and looked into the night from Area 2 for 15 to 20 minutes.

Immediately after interruption of dark adaptation, the subject was quickly led to the starting point and told to traverse the course using both eyes. This took about 15 seconds. He was rapidly reminded to stay as far away from the guideline as possible, to make sure that he was following the direction of the path, and to drop one poker chip straight down every time he placed his right foot on the ground. He was also told to step rather high as he walked, so as not to snag the string grid.

Thus far the procedure described is that used for Study 1. The procedure used for the other studies differed only in that varying periods of readaptation to the dark were inserted between viewing on the simulated intensifier and traveling along the guideline under two of the three experimental conditions. For readaptation, the subjects again looked into the night from Area 2 after quitting the visual apparatus.

Throughout data collection for all the studies, measurements of the ambient illumination were made at intervals with the Gamma Photometer. Because the experimenter who made the measurements had other duties as well, it was not possible to follow a predetermined time schedule for recording the light readings. The readings and the time (EST) at which they were recorded are summarized in Appendix D. All readings were taken in Area 2; the photometer head was held five feet above and parallel to the ground.

Performance Measurement

The primary measure of performance was the average distance between the guideline and the path of poker chips. After a subject had completed an experimental run, the distance of each chip from the guideline was recorded. In recording, an experimenter visualized a 5-foot square of string in which a chip lay as being composed of nine smaller squares, 20 inches per side. The experimenter judged in which of the smaller squares the chip rested and recorded the distance from the center of this 20-inch square (the point at which its two diagonals would cross) to the guideline. These distances lay along an axis or azimuth parallel to the abscissa of Figures 2 and 3.

For illustrative purposes, suppose that a chip rests in grid square No. 130 (Figure 4). In visually dividing the square (Figure 5), the experimenter first judges that the chip lies in the lower right hypothetical square (Figure 5) and then determines the horizontal distance from the center of that 20-inch square to the guideline (Figure 6).

Grid Square 130 and Adjacent Area, Showing Guideline and Position of Chip

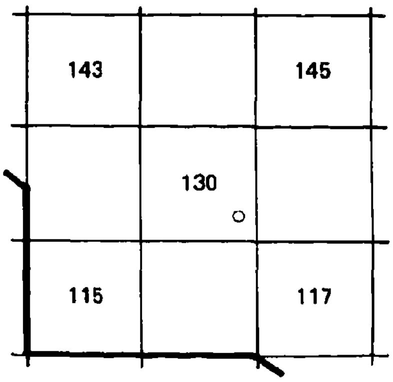

Figure 4

Grid Square 130, Divided Into 20 Inch Squares and
Showing Position of Chip

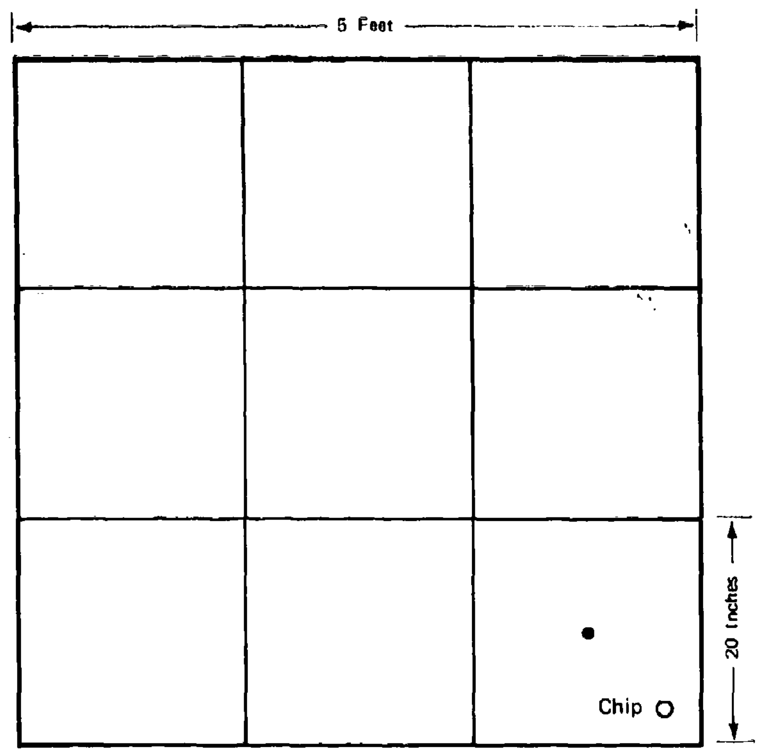

Figure 5

For an experimental run, the distances separating all chips from the guideline were summed and divided by the number of chips dropped. This average distance was used as the unit of statistical analysis. The time in seconds that the subject required to walk along the guideline was also recorded.

RESULTS

Throughout the running of the four studies of Experiment I, visual inspection of the chip paths disclosed that subjects always walked a course which was a fair approximation of the guideline pattern.

Distance-from-guideline data for each of the four studies were initially explored with an analysis of variance. Differences between means were analyzed with Newman Keuls tests (7). In all analyses, $p<.05$ was used as the criterion for establishing statistically significant differences.

The analyses assess the intrasubject effect of both dark adaptation interruptions and readaptation intervals on lateral walking performance. Also assessed were the effects of (a) different times of night, and (b) different nights, on lateral walking performance by an intersubject comparison of both groups and nights.

Grid Square 130, Showing Method of Measuring Distance From Chip to Guideline

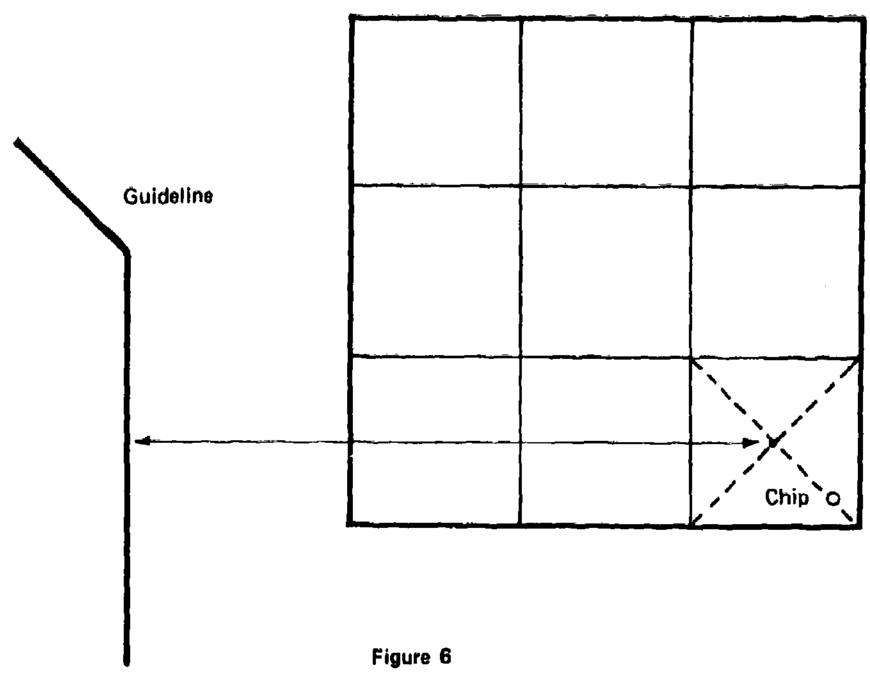

Figure 6

Study I

Analysis of all distance data for Study 1 showed a significant effect only for dark adaptation interruptions (Table 2). Further examination showed that the means of the three interruption conditions differed significantly from one another. The guideline could be

Table 2

Analysis of Variance of Average Distances From the Entire Guideline: Study 1

Source of Variation	*df*	Mean Square	*F*	*p*
Between Subjects				
Nights	2	25785.70	2.82	*NS*
Groups	1	9985.70	1.09	*NS*
Nights x Groups	2	9186.65	1.00	*NS*
Subjects Within Groups	24	9151.98		
Within Subjects				
Interruptions	2	30284.45	46.69	$<.01$
Interruptions x Nights	4	1004.45	1.55	*NS*
Interruptions x Groups	2	412.55	<1	
Interruptions x Nights x Groups	4	111.45	<1	
Interruptions x Subjects	48	648.62		

Mean Divergence From the Guideline for Each Segment and Each Interruption Condition: Study 1

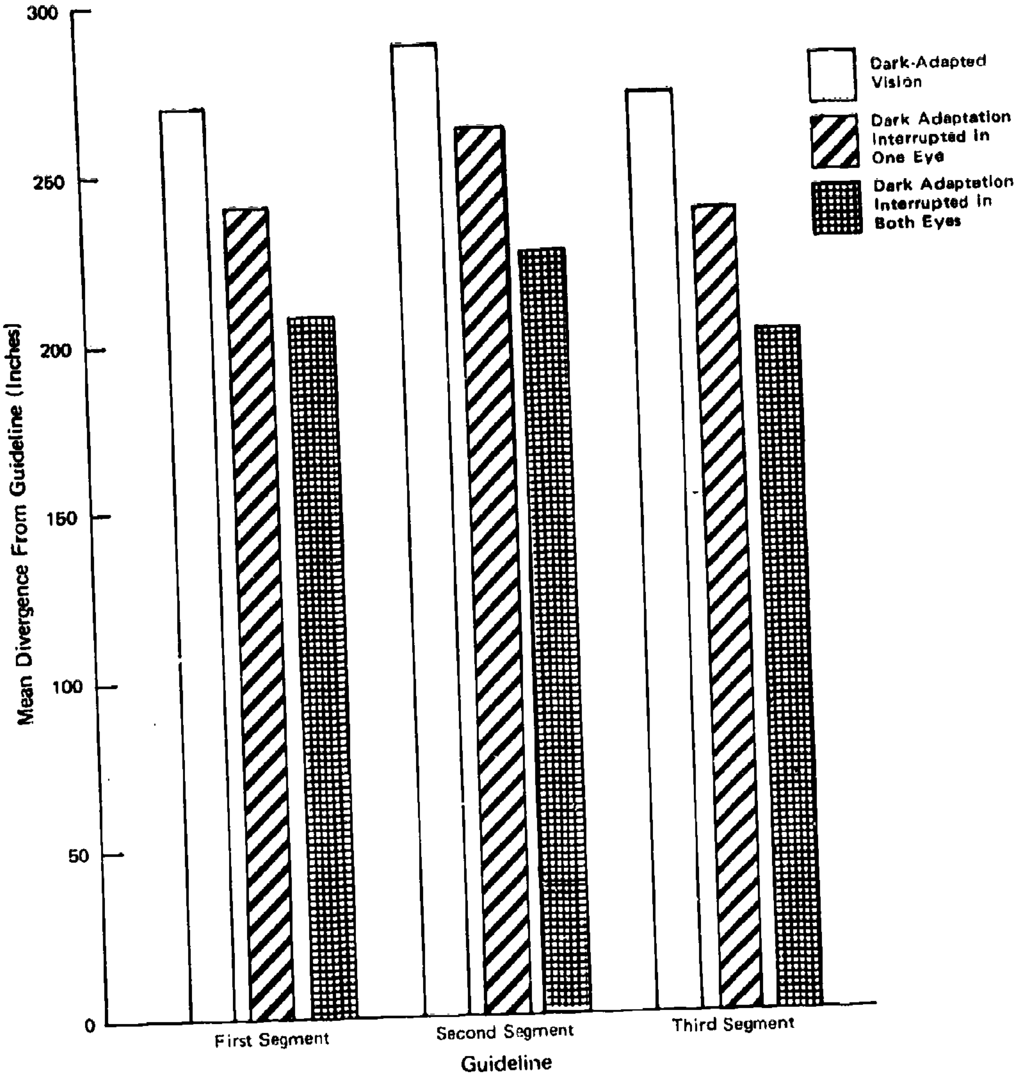

Figure 7

followed at the greatest distance (mean, 277 in.) when there was no interruption of dark adaptation, at the next greatest distance (mean, 249 in.) when dark adaptation was interrupted in one eye, and at the smallest distance (mean, 214 in.) when dark adaptation was interrupted in both eyes.

On the average, then, a dark-adapted soldier saw the guideline from about 20% farther away than a soldier with interruption of dark adaptation alternately in both eyes for 10

minutes, and from about 10% farther away than a soldier with interruption of dark adaptation in one eye for five consecutive minutes.[6]

As noted, visual sensitivity improves with time in the dark after exposure to light. It is therefore possible that distance from the guideline was affected less by interruption of dark adaptation nearer the end of the guideline than at its beginning. To check this possibility, the 70x100-foot area containing the guideline and string gridding was divided transversely into three segments. The first segment measured 70x30 feet, the second 70x40 feet, and the third 70x30 feet. Average distance scores for each segment were generated by dividing the sum of the distances from a subject's chips to the guideline within a given segment by the number of chips he dropped in that segment.

As with the entire body of data (Table 2), a three-factor analysis of variance, with an intrasubject factor of dark adaptation interruptions, was applied to the data from each of the three segments. Subsequent comparisons were made with Newman Keuls tests. For all segments, the results of these analyses display the same relationship among the means of the three conditions of dark adaptation interruption that prevailed in the analysis of distance data for the entire guideline (Figure 7). The greatest deviation from the guideline occurred under dark adaptation, and the smallest under alternate interruption of dark adaptation in both eyes, with intermediate deviation under interruption of dark adaptation in one eye. A significant return of visual sensitivity did not occur while the guideline was being followed.

A three-factor analysis of variance, like the one in Table 2, showed no significant differences in mean time to walk along the entire guideline for dark adaptation interruptions, nights, and groups.

Study 2

Analysis of all distance data for Study 2 showed a significant effect only for readaptation intervals (Table 3). Additional tests showed that the mean distance for the 0-minute readaptation interval (229 in.) differed significantly from the mean for the 3-minute readaptation interval (269 in.), and from the mean for the 6-minute readaptation interval (276 in.). However, the mean of the 3-minute readaptation interval did not differ significantly from

Table 3

Analysis of Variance of Average Distances From the Entire Guideline: Study 2

Source of Variation	df	Mean Square	F	p
Between Subjects				
Groups	1	16100.80	1.72	*NS*
Subjects within Groups	8	9336.75		
Within Subjects				
Readaptation Intervals (0, 3, 6)	2	6379.25	11.82	$<.01$
Readaptation Intervals x Groups	2	198.45	<1	
Readaptation Intervals x Subjects	16	539.62		

[6] Although no tabulation was made, some subjects reported discomfort such as dizziness and nausea when only one eye was stimulated; i.e., adaptation imbalance. No discomfort was reported when both eyes were stimulated. Whether or not such symptoms would persist after several experiences of adaptation imbalance is not known. Additional studies should be conducted to establish the extent and duration of the discomfort.

the mean of the 6-minute interval. These findings suggest that the effects of interruption of dark adaptation had worn off within three minutes after both eyes had been exposed to intensifier stimulation for five consecutive minutes.

A two-factor analysis of variance, like the one in Table 3, was applied to the data from each of the three guideline segments. The analyses applied to the data from the first two segments showed a significant effect only for readaptation intervals. The analysis applied to

Mean Divergence From the Guideline for Each Segment and Each Readaptation Interval: Study 2

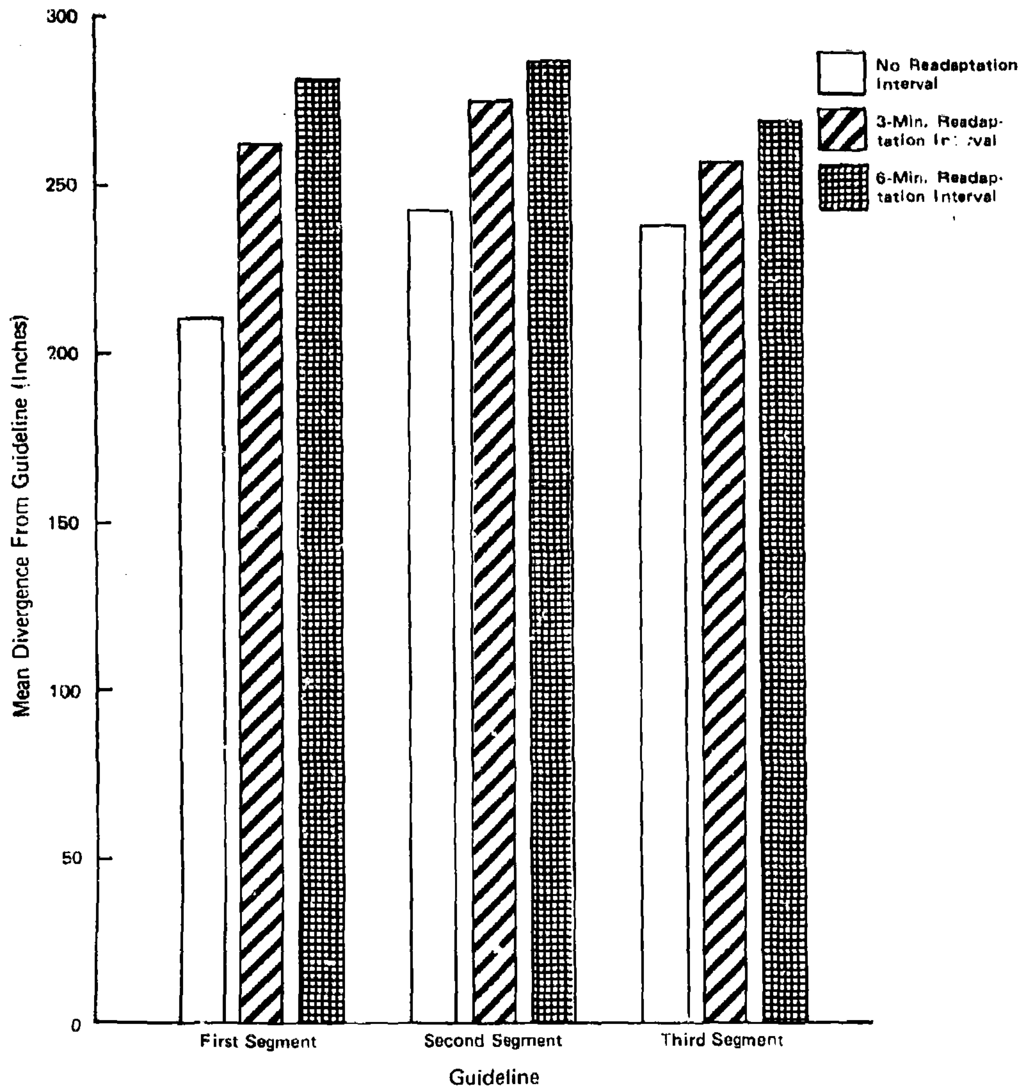

Figure 8

the data from the third segment showed no significant effects. Further analysis of the significant effect of readaptation intervals in the first two segments showed that no readaptation resulted in significantly less divergence from the guideline than either three minutes or six minutes of readaptation (Figure 8), along the bulk of the length of the guideline. But lack of a significant effect of readaptation intervals in the third segment of the guideline indicates that traversing the first two segments took enough time that dark adaptation was restored for traversing the third segment.

Study 3

Analysis of all distance data for Study 3 showed a significant effect only for readaptation intervals after both eyes had been exposed to the simulated intensifier for five consecutive minutes (Table 4). Additional tests showed that the means of the three readaptation intervals differed significantly from one another. The distance from the guideline was largest after two minutes of readaptation (273 in.), next largest after one minute of readaptation (253 in.), and smallest after no readaptation (232 in.).

Table 4

Analysis of Variance of Average Distances From the Entire Guideline: Study 3

Source of Variation	*df*	Mean Square	*F*	*p*
Between Subjects				
Groups	1	1.60	<1	
Nights	1	4506.60	<1	
Groups x Nights	1	1664.40	<1	
Subjects Within Groups	16	4663.73		
Within Subjects				
Readaptation Intervals (0, 1, 2)	2	8591.40	9.40	<.01
Readaptation Intervals x Nights	2	160.20	<1	
Readaptation Intervals x Groups	2	1189.10	1.30	*NS*
Readaptation Intervals x Nights x Groups	2	420.90	<1	
Readaptation Intervals x Subjects	32	913.42		

The positive relationship between readaptation intervals and distance from the guideline also prevailed within each of the three guideline segments. A three-factor analysis of variance, like the one in Table 4, was applied to the data for each of the three guideline segments. All three analyses showed a significant effect for readaptation intervals (Figure 9). Further tests showed that in all three segments one minute of readaptation allowed significantly greater divergence from the guideline than no readaptation, and that two minutes of readaptation allowed significantly greater divergence than one minute.

A three-factor analysis of variance, like the one in Table 4, showed no significant differences in mean time to walk along the entire guideline for readaptation intervals, nights, and groups.

Study 4

Analysis of all the distance data for Study 4 showed no significant effects (Table 5). Hence, the mean distance for 2-minute readaptation intervals (265 in.) did not differ significantly from either the mean for the 1-minute readaptation intervals (293 in.) or the mean for

Mean Divergence From the Guideline for Each Segment and Each Readaptation Interval: Study 3

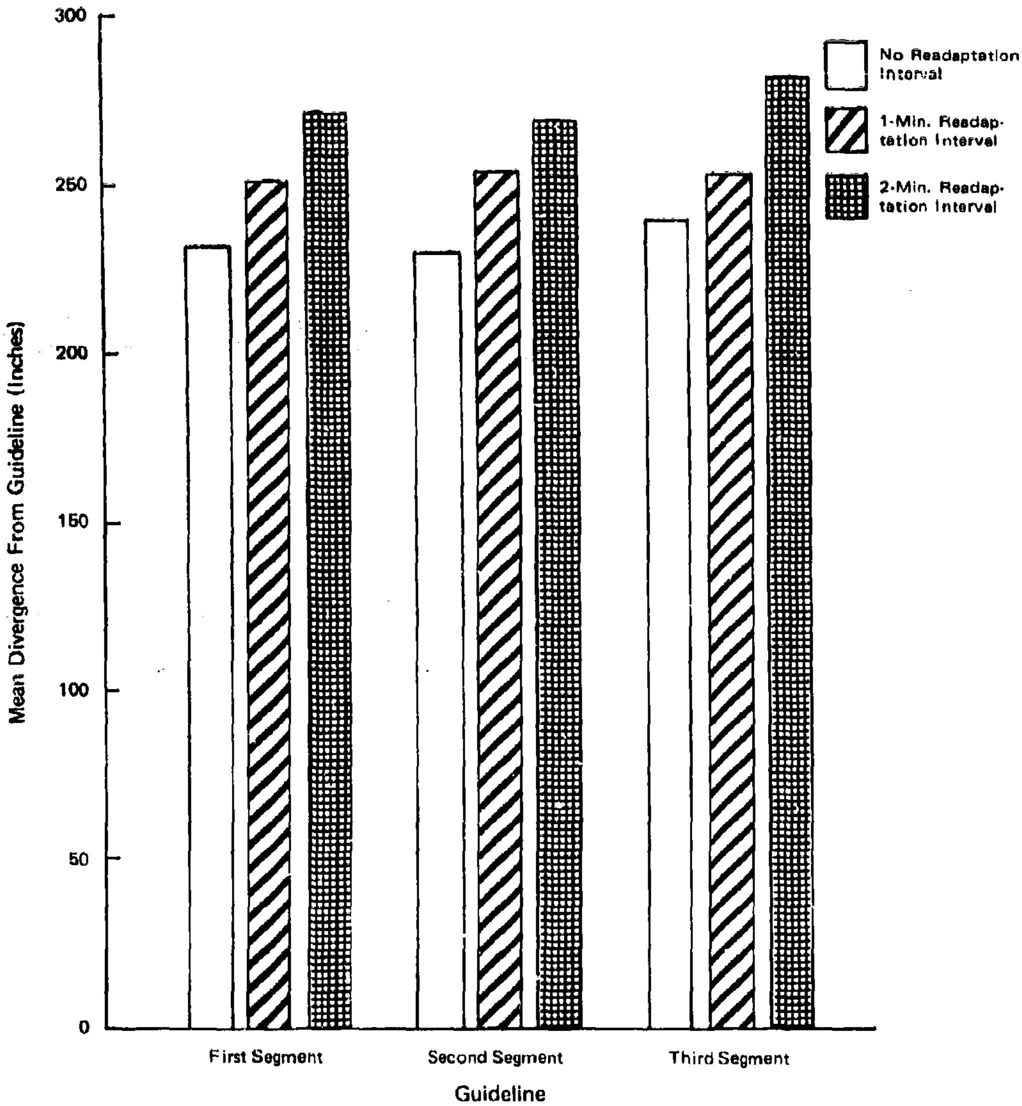

Figure 9

no readaptation (269 in.). Mean divergence from the entire guideline, then, was not affected significantly by one minute or two minutes of readaptation after one eye had been exposed to the simulated intensifier for five consecutive minutes.

A two-factor analysis of variance, like the one in Table 5, was applied to the data for each of the three guideline segments. No significant effects were found for the first two guideline segments. Analysis of the data from the third guideline segment, however, showed

Table 5

Analysis of Variance of Average Distances From the Entire Guideline: Study 4

Source of Variation	*df*	Mean Square	*F*	*p*
Between Subjects				
Groups	1	18950.60	<1	
Subjects Within Groups	8	24597.69		
Within Subjects				
Readaptation Intervals	2	2259.25	2.70	*NS*
Readaptation Intervals x Groups	2	1904.60	2.27	*NS*
Readaptation Intervals x Subjects	16	837.61		

a significant effect for readaptation intervals. Further tests showed a significant difference between the mean distance for two minutes of readaptation (253 in.) and the mean for the other two readaptation intervals, but not between the mean for no readaptation (285 in.) and the mean for one minute of readaptation (300 in.). In contrast with the results of Studies 2 and 3, the results of this study suggest a negative relationship between distance from the guideline and readaptation intervals near the end of the guideline, but no significant relationship between the two over most of the guideline (Figure 10).

A two-factor analysis of variance, like the one in Table 5, showed no significant differences in mean time to walk along the entire guideline for readaptation intervals and groups.

DISCUSSION

It was demonstrated in Study 1 that a prolonged interruption of dark adaptation by simulated image intensifiers decreases the lateral distance at which a white, ground-mounted guideline may be seen and followed with both eyes under starlight conditions. In following it, the soldier who has just finished using an intensifier must keep significantly closer to the line than a dark-adapted soldier.

Insofar as guidelines are used to describe dangerous situations, this finding suggests that interruption of dark adaptation through extended intensifier employment can be dangerous. For instance, during cross-country movement the dark-adapted soldier will see and respond to minefield or radiation boundaries marked by white guidelines at greater distances than the soldier who is not fully dark adapted.

Provided that five consecutive minutes are required to reconnoiter an area completely with one eye, alternating an intensifier between the two eyes theoretically results in only 2½ minutes of intermittent scanning per eye. Yet in Study 1, 10 minutes of scanning by both eyes is compared with five minutes of scanning by one eye in determining the effects of interrupting dark adaptation. Inherent in the comparison is the assumption that 10 minutes of alternate scanning by both eyes is needed to secure the visual information gained during five minutes of scanning by one eye. The assumption appears to have some basis in fact. When a simulated intensifier is switched from one eye to another, the terrain point at which the previous scan ended must be relocated, readjustment of the objective lens may be necessary, and refocusing of the eyepiece lens may be required. All this takes time, and certainly extends the duration of the entire scanning period. In the absence of data to the contrary, then, the design of Study 1 seems reasonably realistic from the standpoint of use of monocular intensifiers by one or both eyes.

Mean Divergence From the Guideline for Each Segment and Each Readaptation Interval: Study 4

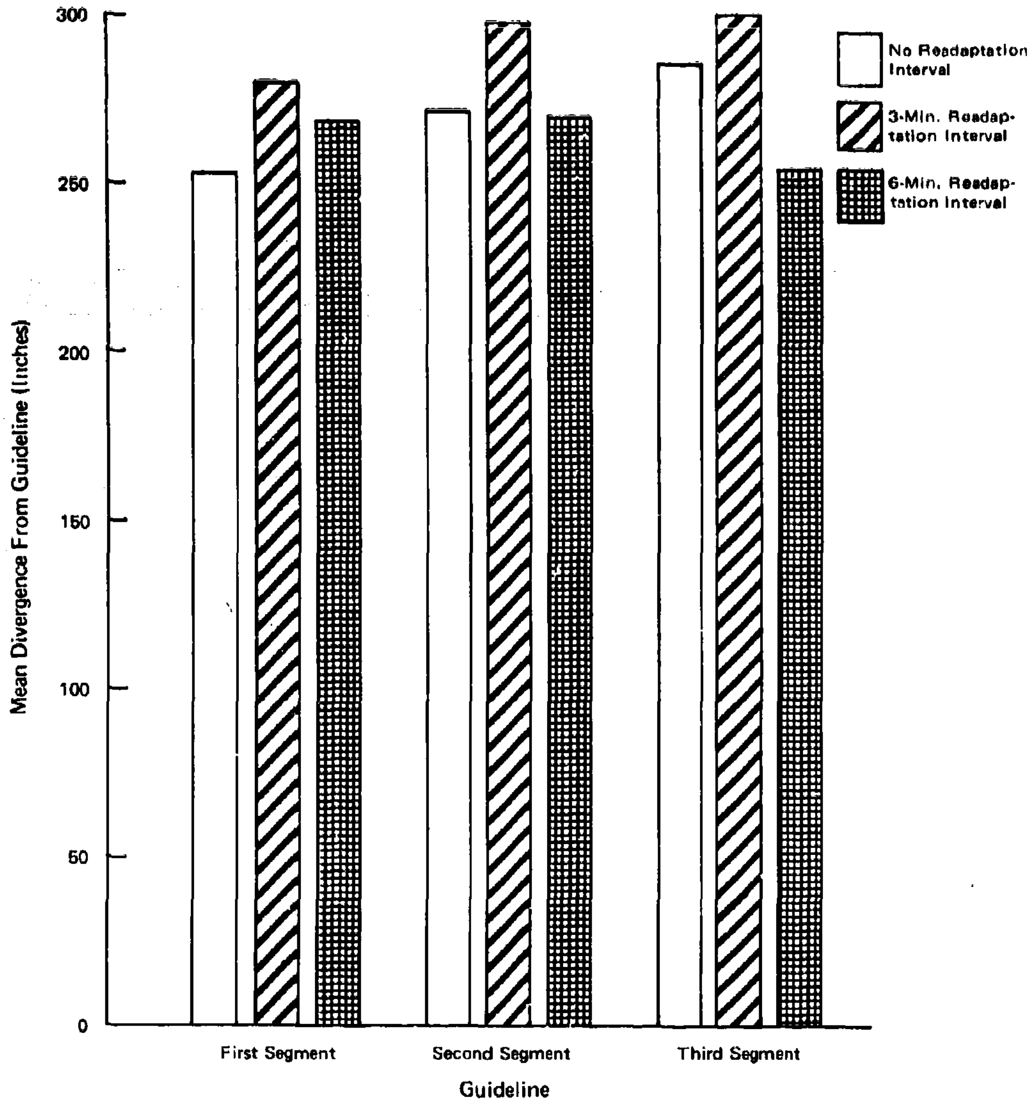

Figure 10

Study 1 shows that interruption of dark adaptation in one eye by a simulated intensifier for five successive minutes resulted in greater divergence from the guideline than a 10-minute interruption of dark adaptation in both eyes alternately for five minutes per eye. At the same time, anecdotal evidence indicated that exposure of one eye to a simulated monocular intensifier produced more "discomfort" than the alternating exposure of both eyes. To an extent, the operational situation will dictate which of these consequences is

least desirable. If cross-country travel through hazardous areas is not imminent, then sustained viewing with both eyes might be allowable in order to minimize discomfort. The same sort of viewing could be permitted if the three-foot gain in divergence afforded by viewing with one eye is not considered critical.

In Studies 2 and 3 dark adaptation was interrupted for five consecutive minutes in both eyes simultaneously with a simulated intensifier. The results show that between two and three minutes of readaptation to the dark are needed to restore divergence from the guideline to what it was for dark-adapted vision. Accordingly, as a general rule, intensifier operators required to walk cross-country should be allowed three minutes of readaptation to the dark before movement is begun after sustained, simultaneous stimulation of both eyes.

In Study 4 dark adaptation was interrupted by five consecutive minutes of simulated intensifier employment in the shooting eye; different readaptation intervals were then provided. Although there was a nonsignificant tendency for guideline divergence to be positively related to the duration of readaptation along the first two segments of the guideline (Figure 10), and though a significant negative relationship existed between the two variables along the last segment, overall divergence from the guideline was not reliably affected by either 0-minute, 1-minute, or 2-minute periods of readaptation to the dark. This main finding is at odds with laboratory findings (1, 2) which show an increase in sensitivity over time in the dark after light stimulation. It also is in contrast with the results of Studies 2 and 3, which show that readaptation time relates positively to distance from the guideline.

Outside the laboratory, evidence of interruption of dark adaptation exists when performance of a task immediately after light stimulation differs significantly from dark-adapted performance on the same task. It also exists when, after light stimulation, different time periods in the dark (readaptation) generate significant changes in task performance. Given the latter condition, the main finding of Study 4 suggests that five consecutive minutes of intensifier stimulation of one eye does not interrupt dark adaptation at all. Yet Study 1, in direct refutation, demonstrated that five consecutive minutes of stimulation of one eye prompted significantly less guideline divergence than full dark adaptation. The main finding of Study 4 is therefore also at odds with the results of Study 1.

In the light of both laboratory findings and the results of Studies 1-3, the main finding of Study 4 is best interpreted as being invalid. The failure to establish a reliable relationship between readaptation interval and overall divergence from the entire guideline in Study 4 probably results from the fact that the small number of experimental subjects reduced the power of the statistical analysis.

In the four studies of Experiment I, time along the guideline was not significantly influenced by either interruption of dark adaptation, readaptation interval, or level of ambient illumination. Evidently the speed at which a guideline will be followed at night—but not the distance at which it can be seen—is unaffected by prolonged employment of an intensifier.

EFFECTS OF INTERRUPTION OF DARK ADAPTATION, BY INTENSIFIER USE, ON RIFLE MARKSMANSHIP (EXPERIMENT II)

PROBLEM AND APPROACH

Although the Starlight Scope, the smallest of the operational intensifiers, may be attached to the M14 and M16 rifles as a direct weapon sight, it is frequently hand-held and used solely for target detection. In case of enemy attack, the operator must attach the scope

to his rifle (a time-consuming operation) or open fire without the scope—with his vision impaired by loss of dark adaptation. The degree to which intensifier employment may affect aimed rifle fire—and ultimate success in repulsing the enemy—has not been systematically studied. For this reason, the three studies of Experiment II were designed to determine, by employing a simulated intensifier, the disruptive effects of dark adaptation interruption on the ability to deliver aimed rifle fire with unaided vision.

RESEARCH METHOD

Apparatus

Four simulated image intensifiers like the one used in Experiment I were employed in Experiment II. As before, the luminance at the eyepiece was maintained at four foot-candles with a photometer. The ambient illumination at night was measured at different intervals with the photometer during the three studies in Experiment II.

The subjects used the M14 rifle with ball ammunition for firing at Type E stationary silhouette personnel targets. In Studies 5 and 7, only olive drab targets were employed; in Study 6, both white and olive drab targets were used.

Subjects

A total of 54 subjects participated in the three studies of Experiment II. Thirty-one enlisted men served in Study 5, 11 in Study 6, and 12 in Study 7. The subjects were trainees at the U.S. Army Training Center, Armor. Relevant personal data obtained from the subjects are summarized in Appendix A.

No attempt was made to select subjects on the basis of rifle marksmanship. It was requested, however, that only subjects qualified under the Basic Rifle Marksmanship Program be assigned.

Design

Study 5 was a comparison of the effects, on firing, of interrupting dark adaptation in the shooting eye for five minutes and interrupting dark adaptation alternately in both eyes for 10 minutes (each eye stimulated alternately for 1-minute periods). The effects of both types of interruption were compared with the effect of not interrupting dark adaptation in either eye. Targets were olive drab, Type E silhouettes at 25 meters. Ten rounds per subject were fired under each of the three conditions.

After poor rifle marksmanship scores were obtained in Study 5, Study 6 was undertaken to establish a less difficult situation in which more hits might be secured. Comparisons were made between white and olive drab, Type E silhouette targets at both 25 and 15 meters. Ten rounds per subject were fired at each of the four target-distance combinations with dark-adapted vision.

Utilizing the findings of Study 6, Study 7 was conducted to re-evaluate the experimental variables manipulated in Study 5. Olive drab, Type E silhouettes at 15 meters were used as targets. Twenty rounds per subject were fired under each of the three interruption conditions.

The three studies were run under starlight. Ambient light measurements taken during each study are listed in Appendix Table D-2. Study 5 extended over three nights; Studies 6 and 7 took one night each.

There were four firing points available throughout the running of the three studies. Ten subjects per night were ordered, but one or two extra subjects came and were run on three of the five experimental nights. On each experimental night, eight subjects were randomly

assigned to two firing groups of four subjects each. The remaining subjects were assigned to a third group.

The same interruption condition was administered simultaneously to all members of a group. The order in which a group was exposed to each of the three interruption conditions in Studies 5 and 7 was randomly determined. In Study 6, all groups first fired at the olive drab/25-meter combination, next at the white/25-meter combination, then at the olive drab/15-meter combination, then at the white/15-meter combination. The conditions of the three studies are summarized in Table 6.

Table 6

Summary of the Conditions for the Three Studies of Experiment II

Study	*N* (Dark-Adapted)	Interruption of Dark Adaptation	Target Condition
5	31	None; in One Eye for 5 Consecutive Min.; in Both Eyes, 1 Min. Alternately for 5 Min. Each.	Olive Drab at 25 meters
6	11	None.	White vs Olive Drab; 15 meters vs 25 meters
7	12	None; in One Eye for 5 Consecutive Min.; in Both Eyes, 1 Min. Alternately for 5 Min. Each.	Olive Drab at 15 meters

Procedure

The subjects were assembled at about 1600 hours and were briefed as a group on the purpose of the study (see Appendix E). After the briefing, the firers were administered the Personal Information Form (Appendix C) which was also used in Experiment I. The subjects were then tested individually on the Armed Forces Vision Tester and the Navy Night Vision Tester. (See Appendix A for data.) Next they were transported to a machine gun assault range. Because it was most shielded from road traffic, this range was the most suitable one at Fort Knox. At the range, four firing points were set up. Range procedures required by G3 Range Control were followed. Two officers, one noncommissioned officer in charge, and four NCOs (one to monitor each firing point) were present. At each point, a shelter half was provided for the men to lie on when they fired. The prone firing position was selected because it most closely approximated the usual combat situation.

Immediately after a group experienced interruption of dark adaptation with a simulated image intensifier, located three feet behind the firing line, all members of the group were rushed to the firing points. Each was handed a loaded weapon and ordered to fire when ready. (The subjects had been carefully instructed not to fire until the target could be clearly distinguished from its background.) Using two stopwatches at each firing point, an experimenter recorded (a) time to first round and (b)duration of fire. Immediately after the range was declared safe by the officer in charge, the four NCOs and each firer went down to

the targets and, using red-filtered flashlights, counted the number of hits and marked them with a black felt pen.

After firing and scoring, the group waited behind the firing line until the two other groups had finished an interruption/firing sequence (Studies 5 and 7) or a distance/target combination (Study 6) before being run again. This means that for subjects run under the dark adaptation condition in Studies 5 and 7, the effects of previous interruption of dark adaptation could dissipate during the running of the two other groups—the duration of this period varied because of previous interruption durations but was about 20 minutes. No interruption of dark adaptation was assumed in Study 6. A group firing with dark-adapted vision was taken to the firing points as soon as the hits of the previous group were recorded. A group experiencing dark adaptation interruption was exposed to the simulated intensifiers immediately after the hits of a previous group were recorded.

Performance Measurement

Three different aspects of firing performance were recorded and analyzed. These included (a) time to first round; that is, the time elapsing between the "commence firing when ready" command and the delivery of the first round; (b) duration of fire; that is, the time elapsing between the delivery of the first and final rounds; and (c) number of target hits.

Firing performance data were subjected to an analysis of variance. Differences between means were explored with Newman Keuls tests (7), and $p<.05$ was used as the criterion for establishing statistically significant differences. The analyses assess (a) the intrasubject effect of interruption of dark adaptation and (b) the intersubject effect of nights.

RESULTS

Study 5

Analysis of time to first round data yielded a significant effect for both interruptions and nights (Table 7). Further examination showed that both interruption of dark adaptation alternately in two eyes and interruption in one eye resulted in a significantly greater mean time to first round than no interruption of dark adaptation (9.9 seconds). The difference between the average time to first round for interruption in both eyes (190.5 seconds) and for interruption in one eye (155.7 seconds) was large, but not statistically significant. Additional tests showed that the average time to first round for the three interruption conditions was

Table 7

Analysis of Variance of Time to First Round Data: Study 5

Source of Variation	*df*	Mean Square	*F*	*p*
Between Subjects				
Nights	2	126144.50	6.48	<.01
Subjects within Nights	27	19459.85		
Within Subjects				
Interruptions	2	284737.50	21.97	<.01
Interruptions x Nights	4	34130.17	2.63	*NS*
Interruptions x Subjects	54	12960.91		

significantly longer on Night 2 than on Nights 1 and 3. The difference between Night 1 and Night 3 was not significant.

Although the mean time to first round for the three interruption conditions was a function of nights (more explicitly, a function of extraneous factors that characterized nights, such as illumination level, temperature, etc.), the relationship among the time to first round means for the three interruption conditions was not significantly affected by nights.[7] This is indicated by the absence of a significant interaction between Nights and Interruptions in Table 7. Thus, 10 minutes of interruption of dark adaptation alternately in both eyes and five minutes of interruption of dark adaptation in the shooting eye produced significantly greater mean time to first round than no interruption of dark adaptation, on each of the three nights of the study. Figure 11 illustrates the stable relationship among the means of the three interruption conditions for the three nights.

Mean Time to First Round for Each Night of Study 5

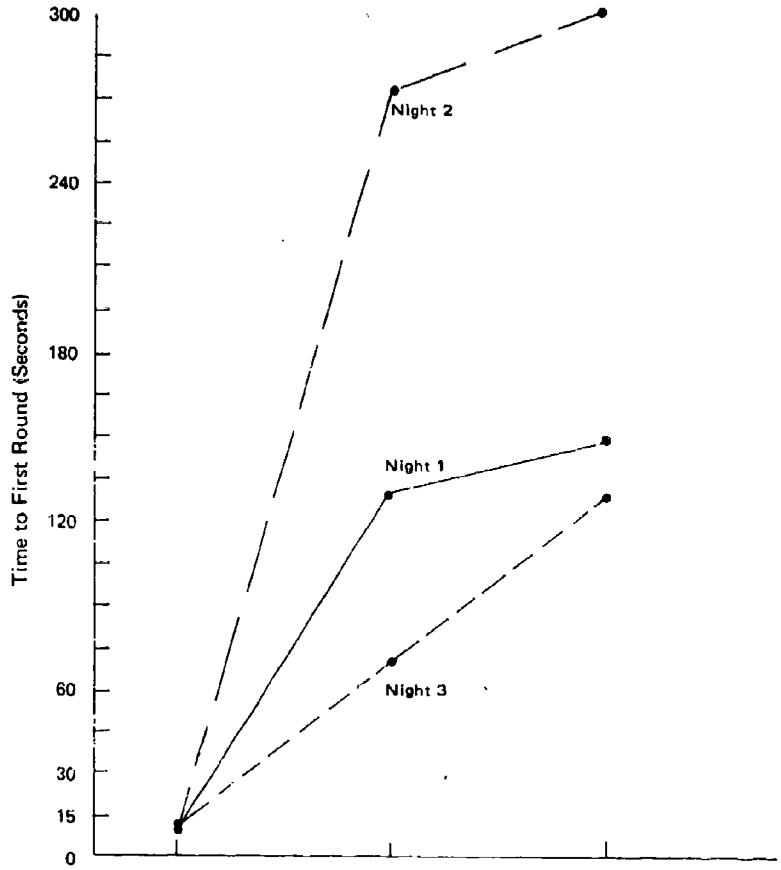

Figure 11

[7]Measures of ambient illumination were obtained on Nights 1 and 3, but not on Night 2 (see Appendix Table D-2). Consequently, a night-by-night comparison of illumination levels is impossible.

The analysis of duration of fire data (Table 8) showed a significant effect for interruptions. Further examination revealed a significant difference between no interruption of dark adaptation and the two interruption conditions, but not between the two interruption conditions themselves. Averaged over all three experimental nights, no interruption of dark adaptation generated a mean of 44.2 seconds, interruption of dark adaptation in one eye a mean of 78.6 seconds, and interruption of dark adaptation alternately in both eyes a mean of 93.4 seconds. These means are plotted in Figure 12.

Table 8

Analysis of Variance of Duration of Fire Data: Study 5

Source of Variation	*df*	Mean Square	*F*	*p*
Between Subjects				
Nights	2	11448.03	3.66	*NS*
Subjects within Nights	27	3128.11		
Within Subjects				
Interruptions	2	21280.29	6.32	<.01
Interruptions x Nights	4	3896.59	1.16	*NS*
Interruptions x Subjects	54	3365.56		

Accordingly, using time to first round and duration of fire under no interruption of dark adaptation as a basis of comparison shows that 10 minutes of interruption of dark adaptation alternately in both eyes and five minutes of interruption in the shooting eye not only markedly delay the delivery of the first round but also extend the time needed to fire nine succeeding rounds.

The analysis of hit data (Table 9) turned up no significant effects. Neither five minutes of interruption of dark adaptation in one eye (2.6 average hits) nor 10 minutes of interruption alternately in both eyes (1.9 average hits) reduced firing accuracy to a degree significantly below that obtained with dark-adapted vision (3.0 average hits).

Table 9

Analysis of Variance of Hit Data: Study 5

Source of Variation	*df*	Mean Square	*F*	*p*
Between Subjects				
Nights	2	19.37	2.68	*NS*
Subjects within Nights	27	7.22		
Within Subjects				
Interruptions	2	8.84	2.26	*NS*
Interruptions x Nights	4	9.68	2.48	*NS*
Interruptions x Subjects	54	3.91		

As a score of 3.0 hits reflects maximum mean performance in the present situation, it is evident that there was little practical range for measuring a decrement in firing accuracy. Study 6 was therefore conducted to select a situation in which more average hits could be

Mean Duration of Fire (10 Rounds) for Study 5
(3 Nights Combined)

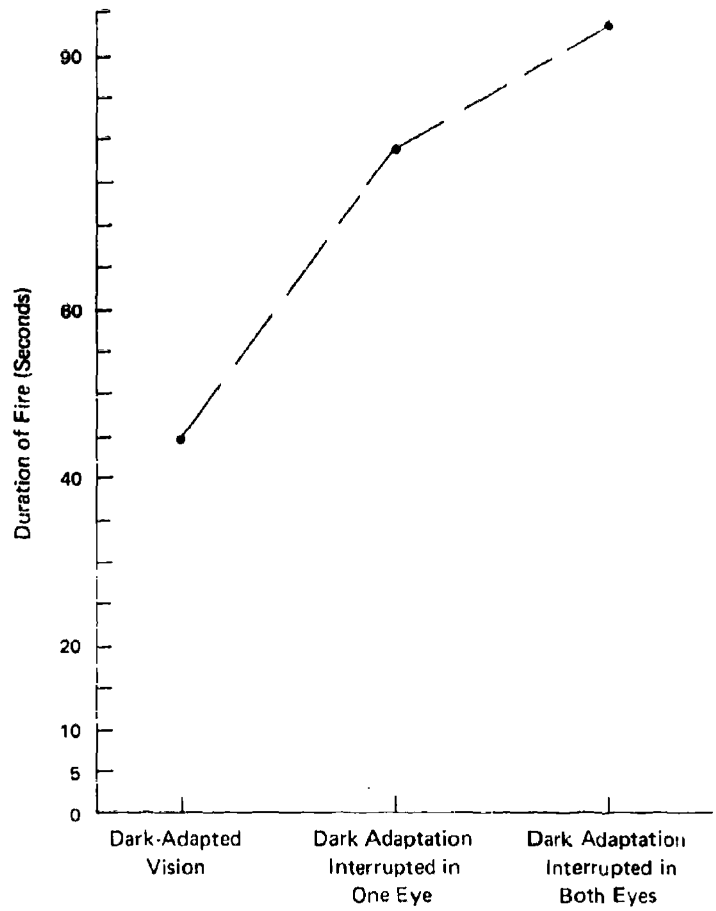

Figure 12

attained with dark-adapted vision, the visual condition which generated the most efficient performance in terms of (a) time to first round and (b) duration of fire.

Study 6

The mean hit scores for each of the four distance/target combinations are shown in Table 10. The table indicates that at 15 meters both the white target and the olive drab target have increased the range (5.4 to 0.0, or 5.0 to 0.0) within which the negative effects of interruption of dark adaptation may appear. The highest average hit performance occurred on the white target at 15 meters (5.4), the next highest on the olive drab target at 15 meters (5.0). The latter was selected for Study 7 instead of the easier white target because

Table 10

Mean Hit Data for Each Target Color at Each Distance: Study 6

Target Distance	Number of Hits	
	Olive Drab	White
15 meters	5.0	5.4
25 meters	2.2	2.1

(a) the difference between the means of the two target/distance combinations was very small, and (b) the olive drab more closely approximates the garb worn by troops attacking at night.

Study 7

To extend further the range along which the negative effects of dark adaptation interruption could appear, 20 rounds per subject were fired at the olive drab target at 15 meters under each of the three interruption conditions.

An analysis of target hits (Table 11) revealed no significant effects for dark adaptation interruption. Thus increasing the hit range within which the negative effects of interruption could appear proved fruitless. Interruption of dark adaptation in the shooting eye produced 9.0 mean target hits, no interruption of dark adaptation 7.7 mean target hits, and interruption of dark adaptation in both eyes 7.8 mean target hits.

Table 11

Analysis of Variance of Target Hits: Study 7

Source of Variation	*df*	Mean Square	*F*	*p*
Between Subjects	11	33.03		
Within Subjects	24			
Interruptions	2	9.33	<1	*NS*
Interruptions x Subjects	22	35.64		

Table 12

Analysis of Variance of Time to First Round Data: Study 7

Source of Variation	*df*	Mean Square	*F*	*p*
Between Subjects	11	1813.54		
Within Subjects	24			
Interruptions	2	5700.53	5.56	<.05
Interruptions x Subjects	22	1024.83		

The mean time to first round for each of the three interruption conditions is shown in Figure 13. In essence, these means describe a circumstance similar to that which prevailed in Study 5 (See Figure 11). Both interruption of dark adaptation in one eye (29.7 sec.) and interruption in both eyes (52.2 sec.) resulted in greater time to first round than no interruption (8.6 sec.). Analysis of the time to first round data showed a significant interruption effect (Table 12). Further examination indicated a significant difference between the mean time associated with interruption alternately in both eyes and the mean time associated with no interruption of dark adaptation. However, the mean time associated with interruption in the shooting eye did not differ significantly from the mean times associated with the other two visual conditions.

Duration of fire means of the three interruption conditions are plotted in Figure 14. Again, there is agreement with Study 5 (See Figure 12). Both interruption in one eye

Mean Time to First Round for Study 7

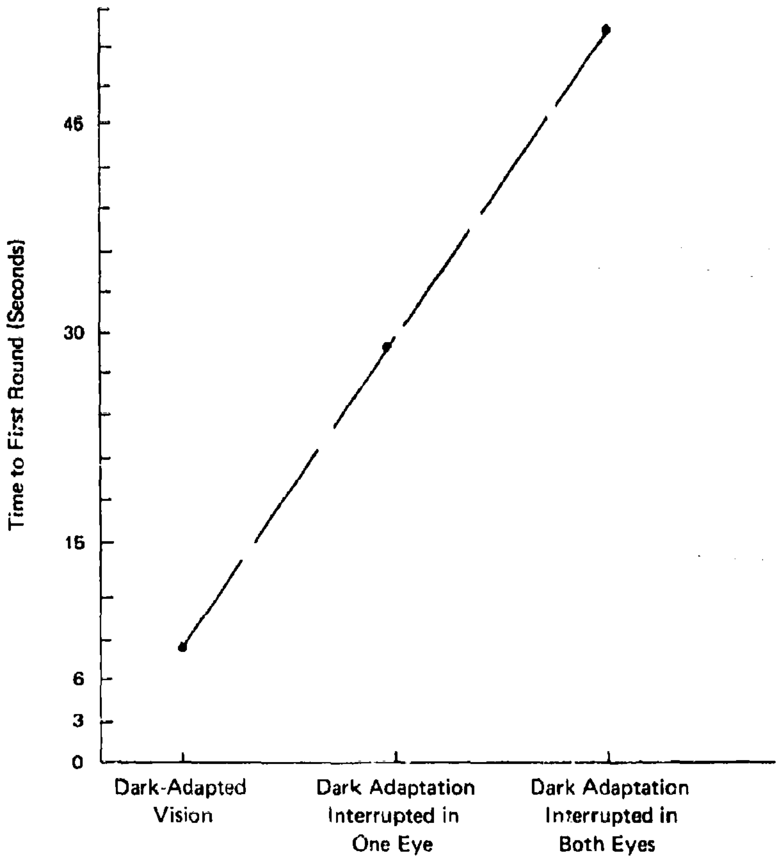

Figure 13

(47.5 sec.) and interruption in both eyes (66.8 sec.) caused longer durations of fire than no interruption of dark adaptation (38.8 sec.). But an analysis of the duration of fire data yielded no significant effects for interruptions or nights (Table 13). Study 7

Table 13

Analysis of Variance of Duration of Fire Data: Study 7

Source of Variation	*df*	Mean Square	*F*	*p*
Between Subjects	11	894.09		
Within Subjects	24			
Interruptions	2	2478.02	3.40	*NS*
Interruptions x Subjects	22	729.72		

Mean Duration of Fire (20 Rounds) for Study 7

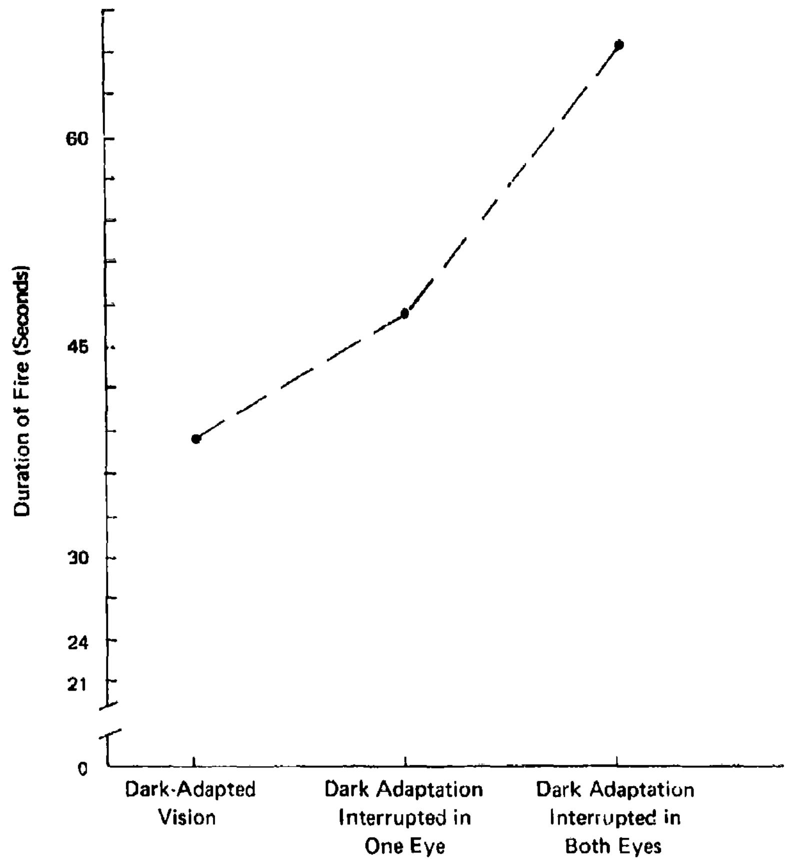

Figure 14

therefore indicates that dark adaptation interruption does not significantly affect duration of fire. Yet Study 5 demonstrated that both interruption in one eye and interruption in both eyes result in significantly longer durations of fire than no interruption.

A test presented by Jones and Fiske (8) permits a joint evaluation of separate findings from independent statistical replications. Applied to the probabilities of the duration of fire Fs generated by dark adaptation interruption in Studies 5 and 7, the test gives a chi-square value which acknowledges the contributions of both studies. The results of this application are contained in Table 14. They show that the

Table 14

Chi-Square Test of Joint Probability of Fs for Dark Adaptation Interruption Conditions: Studies 5 and 7

Study	p	$\text{Log}_{10}\, p$
5	.005	7.6990−10
7	.10	9.0000−10
		16.6990−20

$$\chi^2 = -2(2.3026)\,(-3.3010)$$
$$\chi^2 = 15.20$$
$$df = 4$$
$$p = <.01$$

two probabilities could have occurred consecutively less than one time in a hundred by chance. Consequently, one may reject the general hypothesis that duration of fire is unaffected by dark adaptation interruption.

DISCUSSION

The results of the studies in Experiment II show that fairly prolonged interruption of dark adaptation in one or both eyes through employment of a simulated monocular intensifier affects two aspects of nighttime firing performance. First, it lengthens time to first round with unaided vision by delaying the visual acquisition of the target. Second, it lengthens the time taken to fire a given number of succeeding rounds with unaided eyes. This interpretation of the results rests on the following arguments.

Two separate statistical assessments indicate that time to first round was significantly longer after 10 minutes of exposure of both eyes alternately to a simulated intensifier than under dark adaptation. But only one of the assessments (Study 5) indicated that time to first round was significantly longer than 5 minutes of exposure of one eye to an intensifier than under dark adaptation. Since this assessment was more statistically powerful than the other (Study 7), and since the first-round trends in both assessments were compatible (as shown in Figures 11 and 13), it seems safe to assume that the findings of Study 5 are more valid, and that consequently interruption either in one eye or alternately in both eyes produces greater time to first round than no interruption.

Study 5, along with a joint evaluation of Studies 5 and 7, points out that dark adaptation interruption significantly prolongs duration of fire to a degree beyond that obtained under dark adaptation, a finding not shown statistically by Study 7.

Again, in light of the more statistically powerful nature of Study 5 and the common trend of both studies (as shown in Figures 12 and 14), it seems probable that the analyses applied to the duration of fire data of Study 5 may be viewed as more thoroughly describing the relationship between dark adaptation interruption and duration of fire than Study 7. These analyses showed that both 10 minutes of interruption of dark adaptation alternately in both eyes and 5 minutes of interruption in one eye by an intensifier resulted in lengthier durations of fire than did dark adaptation.

The studies in Experiment II showed that target hits were not affected by interruption of dark adaptation in either one or both eyes with a simulated monocular intensifier.

The findings of Experiment II suggest, then, that monocular intensifier employment may reduce the rapidity with which an attacking enemy is repulsed at night by soldiers who must locate and continually engage a target with aimed rifle fire after laying aside the optical device. The most powerful estimate of this handicap (Study 5) amounts to between 2 and 3 minutes for time to first round and to over half a minute for duration of fire.

A provocative line of further research is suggested by the studies of Experiment II. If only the shooting eye is used in night firing, then it should make no difference when dark adaptation is interrupted in the nonshooting eye. Yet both Studies 5 and 7 show that interruption of dark adaptation in both eyes produces greater time to first round and longer duration of fire than interruption in the shooting eye. Given the extrinsic role of the nonshooting eye in night firing, there should *not* have been a repeated tendency for interruption in both eyes to hinder firing more than interruption in the shooting eye. And while the difference between the two conditions was not significant in either study, the fact remains that two samples of firing behavior have suggested that interruption in both eyes is more disruptive timewise at night than interruption in the shooting eye.

A future study which compares firing immediately after interruption of dark adaptation in the nonshooting eye with firing under dark adaptation could, if the former is more

inhibitive than the latter, give additional information on the role of the nonshooting eye in night firing and suggest relevant military investigation.

CONCLUSIONS

Though image intensifiers increase the surveillance range at night, they also interrupt dark adaptation with an image of considerable brightness. Using performance with dark-adapted vision as a basis of comparison, the studies in this report were undertaken to measure the impact of interruption of dark adaptation on the performance of two military tasks with unaided vision at night: (a) following a ground-mounted guideline at as great a lateral distance as possible; and (b) delivering aimed rifle fire on silhouette targets. Both tasks are among those that might be required of a soldier who has just laid aside an intensifier.

The studies in Experiment I demonstrated that exposing the eyes alternately to a simulated monocular intensifier for 10 minutes (5 min. per eye) and exposing one eye for five minutes resulted in less guideline divergence than not interrupting dark adaptation. Moreover, the guideline could be seen and followed at a greater lateral distance after exposing only one eye than after exposing both eyes alternately. It can be predicted, then, that soldiers who have just employed monocular intensifiers will walk closer to perilous areas marked by guidelines than will dark-adapted soldiers.

After 5 minutes of simultaneous interruption in both eyes by a binocular intensifier, from 2 to 3 minutes of readaptation to the dark are needed to increase a soldier's mean distance from a guideline to that achieved by a dark-adapted soldier. After 5 minutes of interruption in one eye by a monocular intensifier, however, the amount of readaptation interval needed to restore guideline performance to that achieved under dark-adapted vision could not be determined, and further investigation of the matter seems needed.

The second series of studies showed that exposing both eyes to a simulated monocular intensifier for 10 minutes and exposing one eye for five minutes increased both time to fire the first round at a silhouette target and time required to fire a given number of rounds. It appears, then, that exposing one or both eyes to monocular intensifiers slows up both engagement of a target and delivery of aimed rifle fire.

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AND
APPENDICES

LITERATURE CITED

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Appendix A

PERSONAL DATA FOR THE SUBJECTS USED IN BOTH EXPERIMENTS

Table A-1

Biographic Data and Scores on Navy Night Vision Test

Study	Age		Months in Army		Rank		Scores on Navy Night Vision Test[a]	
	Mean	Standard Deviation	Mean	Standard Deviation	Mode	Range	Mean	Standard Deviation
1	19.3	1.3	4.4	1.6	E2	E1-E2	101.3	8.3
2	20.1	1.2	6.7	1.9	E2	E2-E3	97.0	8.4
3	19.6	1.5	6.2	1.5	E2	E2-E3	96.0	13.2
4	19.7	1.2	5.4	0.5	E2	E2	92.2	12.1
5	20.2	1.4	10.5	9.5	E3	E1-E4	74.8	9.3
6	21.3	2.7	16.5	19.6	E2-E3	E2-E4	62.9	11.7
7	20.4	1.3	7.3	4.8	E2	E1-E3	63.2	9.2

[a]A specific device for measuring scotopic sensitivity (9). Performance on the device reflects "large individual differences," and is affected by such factors as time of year, scores being higher on the average in the winter than in the summer. Apparently a score between 58.5 and 69.8 may be assumed to indicatè normal scotopic sensitivity. It will be noted that the scores of the participants in the four studies of Experiment I were much higher than "normal." This was due to a defect in the device, which was corrected before the running of Experiment II.

Table A-2

Acuity Scores on Armed Forces Vision Tester[a]

Study	Left Eye				Right Eye				Both Eyes			
	Near		Far		Near		Far		Near		Far	
	Mode	Range	Mode	Range	Mode	Range	Mode	Range	Mode	Range	Mode	Range
1	$\frac{20}{15}$	$\frac{20}{15}$ $\frac{20}{25}$	$\frac{20}{20}$ $\frac{20}{17}$	$\frac{20}{12}$ $\frac{20}{40}$	$\frac{20}{15}$	$\frac{20}{15}$ $\frac{20}{30}$	$\frac{20}{17}$	$\frac{20}{12}$ $\frac{20}{50}$	$\frac{20}{17}$	$\frac{20}{12}$ $\frac{20}{25}$	$\frac{20}{15}$	$\frac{20}{12}$ $\frac{20}{40}$
2	$\frac{20}{20}$	$\frac{20}{15}$ $\frac{20}{70}$	$\frac{20}{20}$	$\frac{20}{15}$ $\frac{20}{100}$	$\frac{20}{20}$	$\frac{20}{15}$ $\frac{20}{100}$	$\frac{20}{20}$ $\frac{20}{40}$	$\frac{20}{15}$ $\frac{20}{100}$	$\frac{20}{17}$ $\frac{20}{20}$	$\frac{20}{12}$ $\frac{20}{30}$	$\frac{20}{15}$	$\frac{20}{12}$ $\frac{20}{40}$
3	$\frac{20}{17}$	$\frac{20}{15}$ $\frac{20}{200}$	$\frac{20}{15}$	$\frac{20}{15}$ $\frac{20}{200}$	$\frac{20}{20}$	$\frac{20}{15}$ $\frac{20}{30}$	$\frac{20}{17}$ $\frac{20}{25}$	$\frac{20}{12}$ $\frac{20}{30}$	$\frac{20}{15}$	$\frac{20}{12}$ $\frac{20}{25}$	$\frac{20}{15}$	$\frac{20}{12}$ $\frac{20}{40}$
4	$\frac{20}{20}$	$\frac{20}{15}$ $\frac{20}{25}$	$\frac{20}{20}$	$\frac{20}{15}$ $\frac{20}{30}$	$\frac{20}{20}$	$\frac{20}{15}$ $\frac{20}{25}$	$\frac{20}{20}$	$\frac{20}{15}$ $\frac{20}{25}$	$\frac{20}{17}$	$\frac{20}{15}$ $\frac{20}{20}$	$\frac{20}{15}$	$\frac{20}{15}$ $\frac{20}{20}$
5	$\frac{20}{17}$	$\frac{20}{15}$ $\frac{20}{25}$	$\frac{20}{15}$	$\frac{20}{12}$ $\frac{20}{30}$	$\frac{20}{17}$	$\frac{20}{15}$ $\frac{20}{40}$	$\frac{20}{17}$	$\frac{20}{12}$ $\frac{20}{40}$	$\frac{20}{15}$	$\frac{20}{15}$ $\frac{20}{20}$	$\frac{20}{15}$	$\frac{20}{12}$ $\frac{20}{25}$
6	$\frac{20}{15}$	$\frac{20}{15}$ $\frac{20}{40}$	$\frac{20}{15}$	$\frac{20}{15}$ $\frac{20}{50}$	$\frac{20}{15}$	$\frac{20}{15}$ $\frac{20}{40}$	$\frac{20}{15}$	$\frac{20}{15}$ $\frac{20}{50}$	$\frac{20}{15}$	$\frac{20}{15}$ $\frac{20}{50}$	$\frac{20}{12}$ $\frac{20}{15}$	$\frac{20}{12}$ $\frac{20}{30}$
7	$\frac{20}{15}$	$\frac{20}{15}$ $\frac{20}{25}$	$\frac{20}{20}$	$\frac{20}{15}$ $\frac{20}{25}$	$\frac{20}{15}$	$\frac{20}{15}$ $\frac{20}{30}$	$\frac{20}{15}$	$\frac{20}{15}$ $\frac{20}{30}$	$\frac{20}{15}$	$\frac{20}{15}$ $\frac{20}{25}$	$\frac{20}{15}$	$\frac{20}{12}$ $\frac{20}{25}$

[a]Two fractions in a column should be read as "from $\frac{20}{15}$ to $\frac{20}{20}$."

Appendix B

FORMAL INSTRUCTIONAL SESSION FOR EXPERIMENT I

Each night the subjects assembled as a group (at about 1830) and the following instructions were read:

> "The purpose of our research tonight is to see how well you can follow a white line while staying as far away from it as you can. The white line is a length of engineer tape such as is used in marking pathways through minefields and it is not straight."

At this point, a zigzag chalk line on a blackboard in front of the subjects was brought to their attention. All 70 subjects in this investigation were shown the same zigzag chalk line.

> "Your job is to walk along as far to the right of the line as possible so that it is just barely visible to you. Look at the line over your left shoulder. If you lose sight of it, walk to your left until you can just barely see it again.
>
> "If you should be able to follow the line perfectly, your path would be an exact copy of the line to the right of it."

Here, a broken-line replica of the zigzag chalk line was drawn to the right of it on the blackboard.

> "More than likely, none of you will be able to follow it exactly and will have a path that is only an approximation to the white line."

A broken-line approximation of the zigzag chalk line was then drawn to the right of both it and the broken-line replica.

> "Since some of you have better eyesight than others, it is to be expected that some of you will be able to stay further away from the white line than others as you follow its course.
>
> "Each of you will follow the line three times. You may walk as slowly or as quickly as you can and still just barely see the line, but do not stop walking until you are through. When you are through, you will wait your turn to again follow the line.
>
> "On some occasions, you will stare at a bright light for a specified time just before beginning to follow the line. This light is a copy of a very new visual instrument the Army is just starting to use, and your performance tonight will go a long way in establishing how this instrument is to be used in battle situations. When you are ready to start, we will walk toward the beginning of the line until you can just barely see it."

A broken line, perpendicular to the first segment of the zigzag chalk line, was then drawn toward the start of the zigzag chalk line during this last interruption of the reading of the instructions.

> "After asking if you're ready, I will then blow a police whistle, which means that you are to begin following the line, staying as far to the right of it as possible. There will be someone at the other end of the line to tell you when you have finished.

"You will carry a container holding poker chips in your left hand. Every time your right foot touches the ground, drop a chip as close to this foot as possible with your right hand to mark your path. Do not throw the chips away from your body. You will start dropping chips as soon as you begin walking parallel and to the right of the line, after I blow the whistle.

"There are no obstacles in the area with the white line. However, you should raise your feet high as you walk along, since the area is gridded with strings lying on the ground. There is no such thing as a right or wrong score on these tests.

"Right now, I will take you outside one at a time for a practice trial along a white line. Because we want to simulate night conditions, you will wear goggles for this practice (trial). You will then return to this room.

"You will next be given two vision tests in this building. You will take these tests in the same order that you take your practice trial. You will then be driven to the testing area in groups of five.

"It is necessary to note that neither the lines I drew on the blackboard nor the line upon which you will practice is the same shape as the line out at the testing area.

"Any questions?"

Appendix C

DESCRIPTIVE PERSONAL DATA FORM FOR BOTH EXPERIMENTS

Number__________
Group__________
Recorder__________

DARK FIRE I & II: Information Form

Name ____________________ Rank E-2 ______ E-3 ______ E-4 ______ GT ______ Age ______
Last First MI

Unit ____________________ MOS ______ Current Job __________

Company ____________________

Time in Army ____________________ Time in Current Job ____________________

Shooting Eye ____________________

Scores

1. Armed Forces Vision Tester

Left Eye
Near__________
Far__________

Right Eye
Near __________
Far __________

Both
Near __________
Far __________

Phoria
Lateral ____________________
Vertical ____________________
Depth Perception ____________________

Tester ____________________

2. Devorine Color Plates ____________________

Tester ____________________

3. Navy Vision Test Score ____________________

Tester ____________________

4. Dominant Eye ____________________

Tester ____________________

5. Accuracy of Daytime Firing Score ____________________

Tester ____________________

Appendix D

SUMMARY OF PHOTOMETRIC READINGS DURING THE EXPERIMENTS

Table D-1

Photometric Values Recorded During the Four Studies of Experiment I (Foot-Candles)

Study	First Half			Second Half		
	Mean	Standard Deviation	Time Span	Mean	Standard Deviation	Time Span
1 (Night 1)	(Not Available—Photometer Misread)					
1 (Night 2)	.0023	.0003	2200-2237	.0014	.0002	2315-0042
1 (Night 3)	.0029	.0009	2100-2238	.0018	.0003	2313-0042
2	.0054	.0010	2115-2300	.0033	.0007	2340-0109
3 (Night 1)	.0036	.0004	2150-2320	.0034	.0034	0003-0125
3 (Night 2)	.0024	.0003	2125-2247	.0020	.0001	2331-0043
4	.0017	.0002	2128-2255	.0015	.0001	2339-0112

Table D-2

Photometric Values Recorded During the Three Studies of Experiment II (Foot-Candles)

Study	Mean	Standard Deviation	Time Span
5 (Night 1)	.0028	.0003	2220-2340
5 (Night 2)	(Not Available—Photometer Malfunction)		
5 (Night 3)	.0028	.0003	2013-2155
6	.0023	.0002	2025-2132
7	.0034	.0008	2010-2131

Appendix E

ORIENTATION BRIEFING FOR EXPERIMENT II

You've been selected to participate as subjects in a night firing rifle study. The Army has recently developed a new type of night firing sight called "The Image Intensifier," or "Starlight Scope." This sight does not depend upon projecting any invisible light beam such as is used with infrared; instead, it multiplies the available existing light many times and gives the same image to the eye as when looking through the conventional sniperscope or weapon sight.

It is our assumption that a rifleman in a combat situation may have to resort to conventional night firing techniques due to the scope being inoperative, broken, or when rushed by a number of enemy targets at close range.

We do not have the actual Starlight Scope for this study, but we have made simulation devices which duplicate the intensity presented to the eye by the Starlight Scope. When looking through the scope, the eye becomes daylight adapted; and if a person had to put the scope aside quickly for any reason, it would take time for the eye to adjust to the darkness. We're interested in finding out how long it takes for your eyes to adjust, and how much it will affect your night firing, if any. In this study we're using rifle firing as the vehicle to find out if your vision is affected, when you resort to conventional means of night firing after looking through the simulators.

You will be firing at standard OD silhouettes, at 25 meters distance, with ball ammunition. The rifles have been previously zeroed for you; and you will be given an opportunity to practice in order for you to get the feel of the rifle, as some of you may not have fired in some time. An assistant instructor will be at each firing point and will load the weapon for you and clear it. You will fire from the prone position.

Each of you will fire under three conditions: (a) Straight dark adapted, as you would under normal night firing; (b) one eye light adapted and the other dark adapted, and then required to fire utilizing standard night firing procedures; (c) both eyes light adapted by alternating viewing with each eye for predetermined amounts of time, and then required to fire utilizing standard night firing procedures. We will vary the amounts of time you will be looking through the simulators, and you will be told so by the experimenter at each firing point.

There will be no time limit placed on the firing; but we do stress that you fire when you actually see the target, and not fire because someone else is firing. Standard range procedures will be followed, and the firing will be controlled by the officer in charge of the range.

Are there any questions?

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13. ABSTRACT

To determine how interruption of dark adaptation (by using an intensifier) affected performance of military tasks with unaided vision at night, two series of studies were conducted. In one series, 70 subjects walked parallel to a guideline, keeping as far as possible to the right; in the other series, 54 subjects fired the M14 rifle at silhouette targets. Interruption of dark adaptation with a simulated monocular intensifier in the shooting eye or both eyes just before the task was begun decreased the horizontal distance at which the guideline was followed. A readaptation interval of two to three minutes after interruption of dark adaptation by a binocular intensifier restored performance to the level under dark-adapted vision. Interruption of dark adaptation just before rifle firing lengthened time to first round and duration of fire, but did not lessen accuracy.

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	ROLE	WT	ROLE	WT	ROLE	WT
Dark Adaptation						
Intensifiers						
Military Training						
Night Vision						
Night Warfare						
Optical Detection						
Optical Instruments						
Optical Scanning						
Performance at Night						
Visual Perception						

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